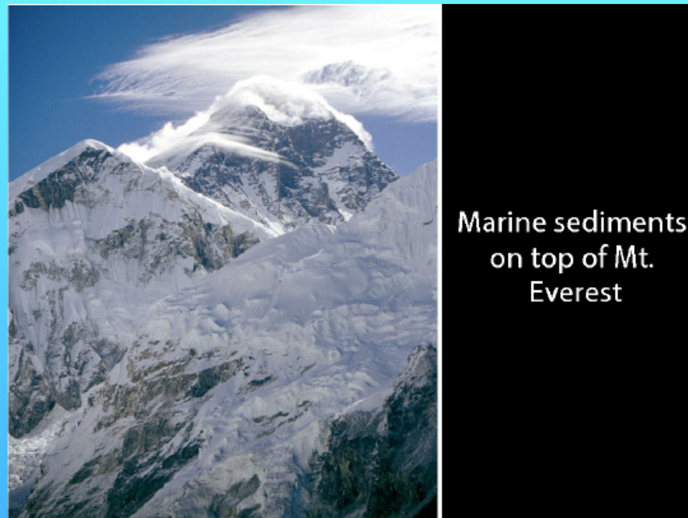
Chapter 2 – Plate tectonics



Chapter 2 Opener
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Definition:

Plate tectonics: the theory that the earth's surface consists of a mosaic of internally rigid plates that move relative to each other

Plate boundaries: zones of faulting that separate extensive, internally rigid areas of the crust. Plate boundaries separate plates and are where the vast majority of deformation within the crust is concentrated.

Alfred Wegener - Wrote first exposition of multiple lines of evidence that continents were joined in distant geologic past – 1915 – German meteorologist. Theory of continental drift – NOT THE SAME as plate tectonics, but the key precursor. Postulates the continents plow through ocean basins and thus move over geologic time.

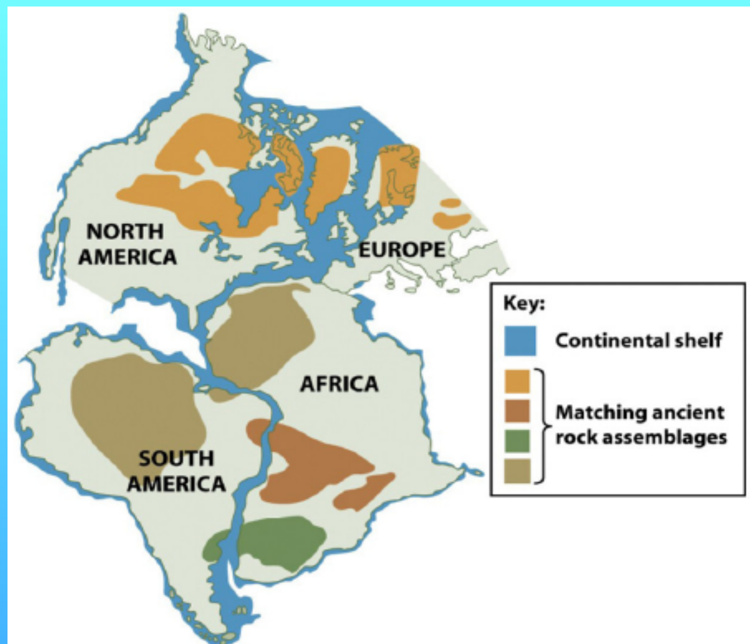

Figure 2-1
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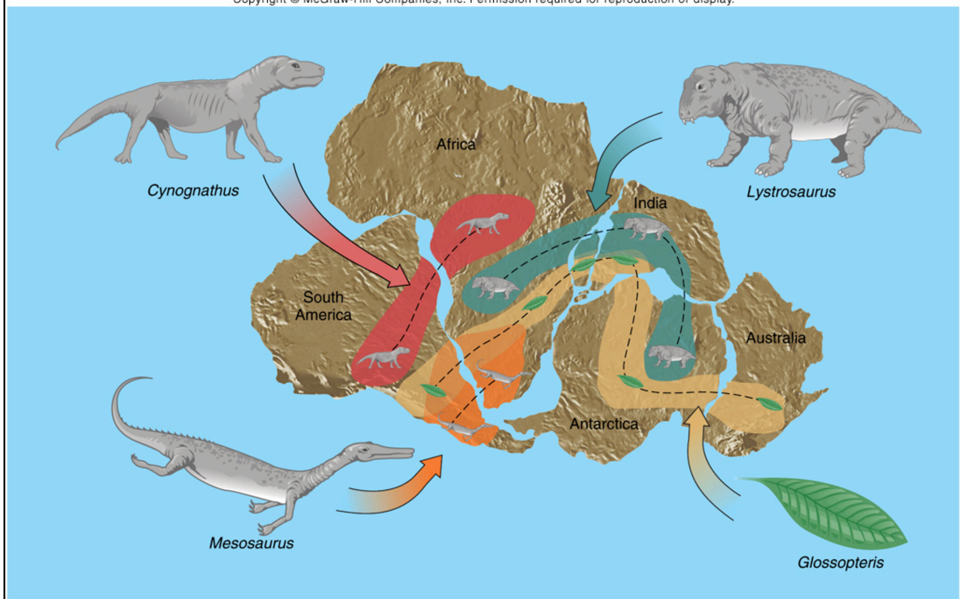
Fig. 19.03



Why did the hypothesis of continental drift fail back in the 1920s ?

Main objection: the lack of any force strong enough to cause a continent to plow through strong oceanic crust

In 1928, a British geologist Arthur Holmes proposed that the Earth's interior convects as heat moves from the hot core toward the cooler surface and that continents and oceanic crust both move as they are dragged by convection.

Until World War II, humankind's view of Earth limited – almost nothing was known about the 70% of the surface that lay beneath water.

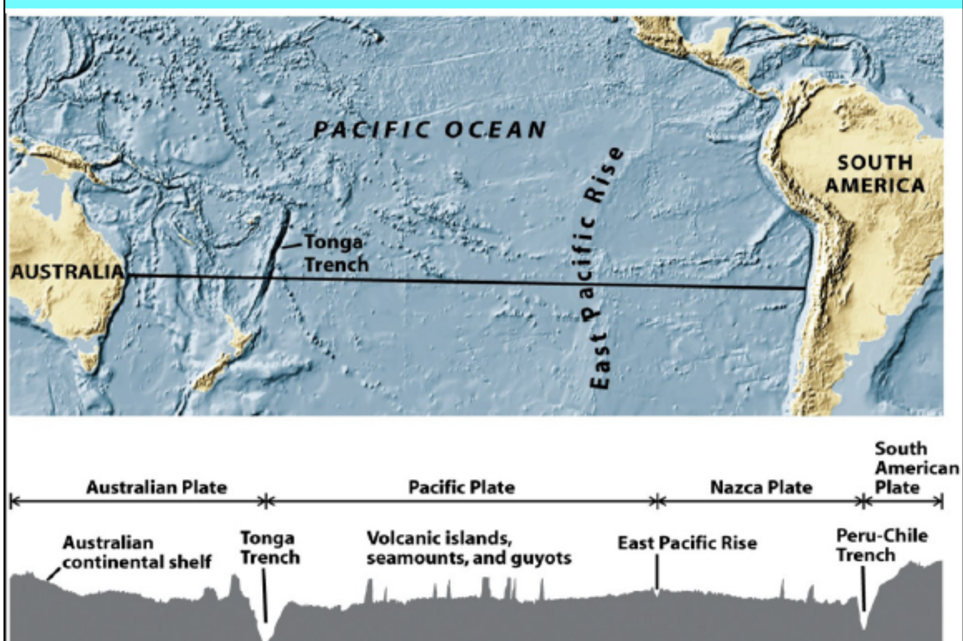


Figure 20-22
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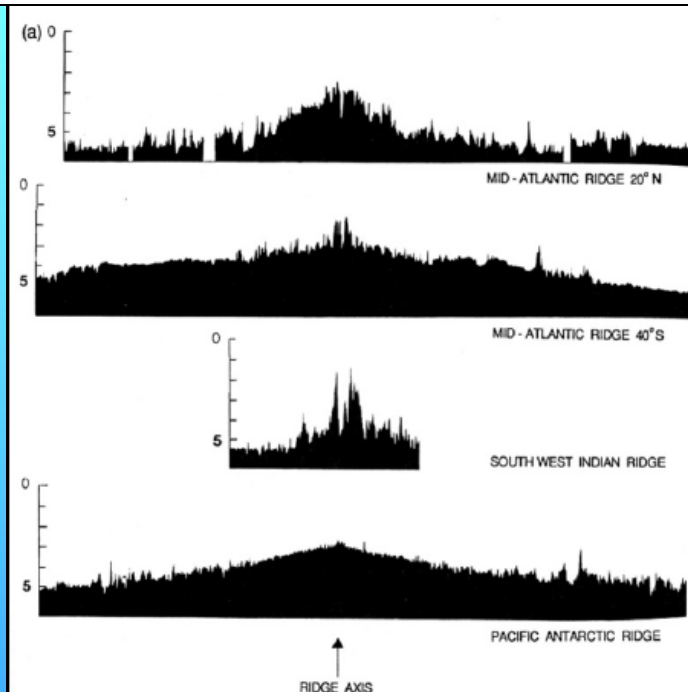
Post-WW II, increasing oceanographic research defined global, high-standing ridges (mountains) in the ocean basins



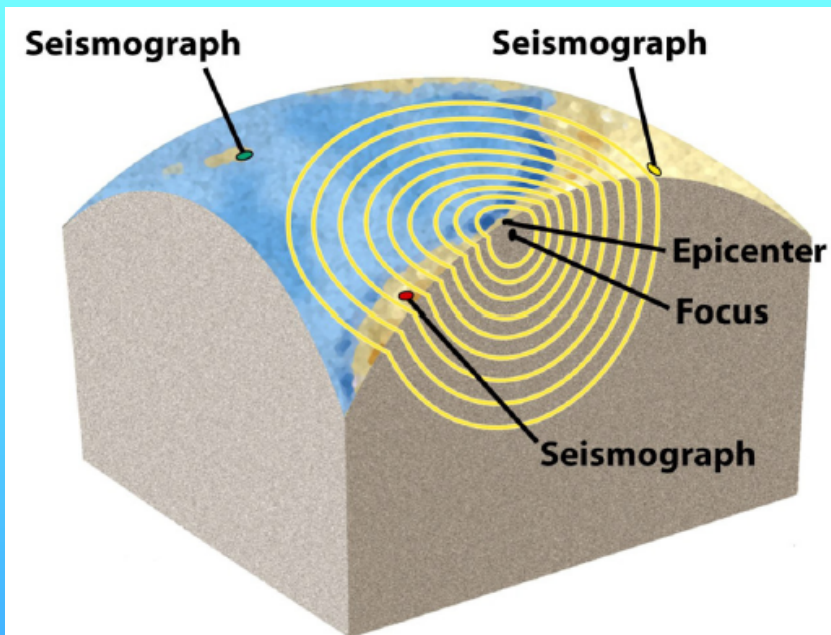


Figure 13-6 part 1
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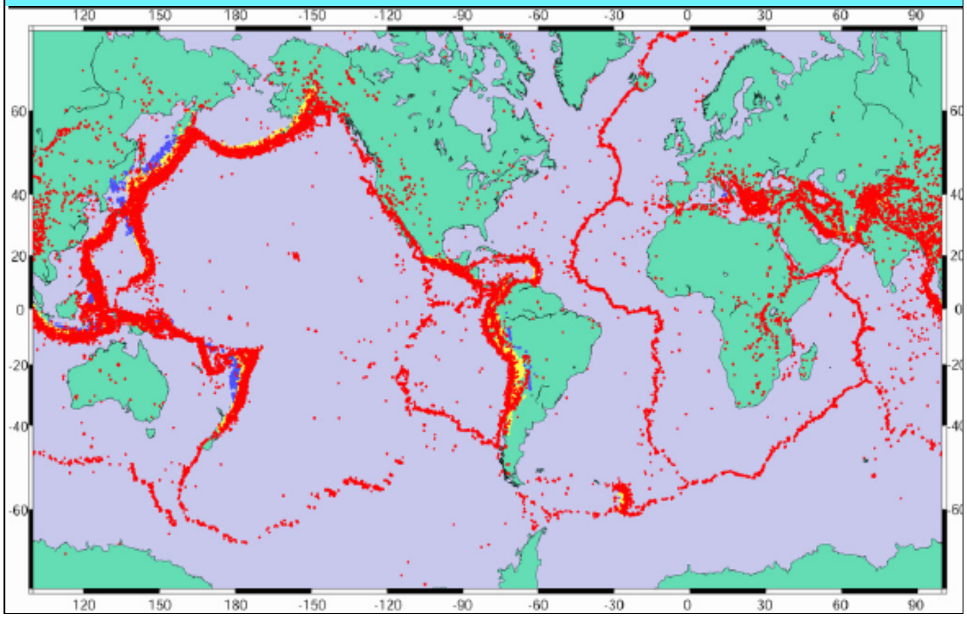
1963-2000 earthquakes – concentrated pattern rather than dispersed – what does it mean ?



Earthquakes coincide with high point of mid-ocean ridges.

Evidence for faulting and deformation concentrated at these locations.

Figure 2-3
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Geodynamo causes two-pole magnetic field. BUT, magnetic pole is stable pointing EITHER north or south and flips occasionally. These flips are called field reversals and are recorded in iron-bearing rocks.

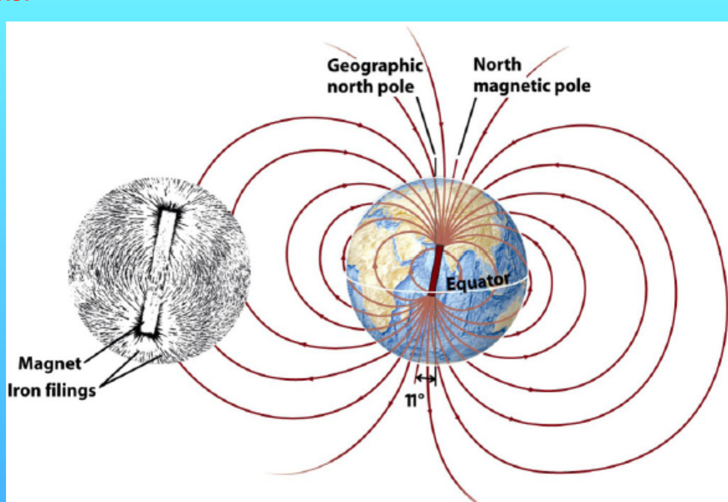

Figure 1-12
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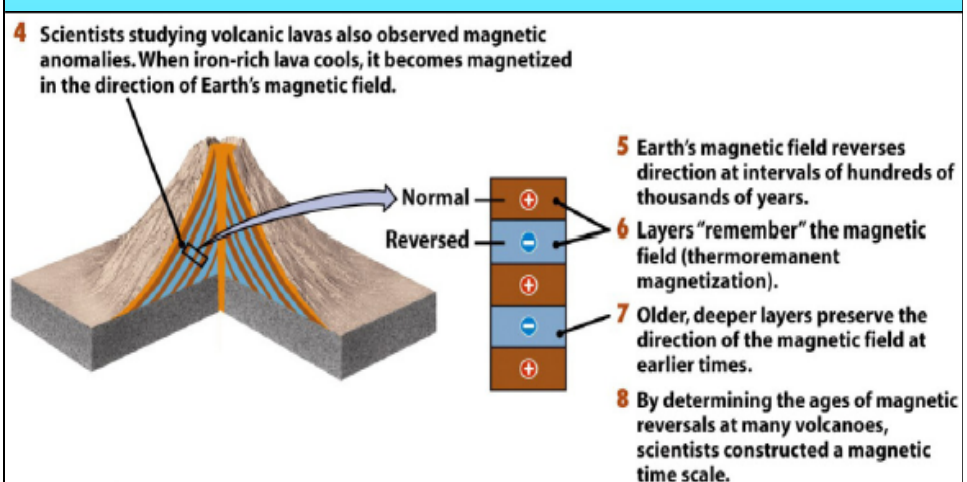

Figure 2-10 part 2
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Building a geomagnetic reversal time scale.
Step 1: Find a thick column of iron-bearing igneous rock (volcano!)
Step 2: Use magnetometer to find where rock paleomagnetic field reverses,
Step 3: Date the rocks just below and above the reversal.
Step 4: Repeat at other locations to see if the reversal is global.
Step 5: If Yes for Step 4, have identified a global field reversal !
Step 6: So what ?

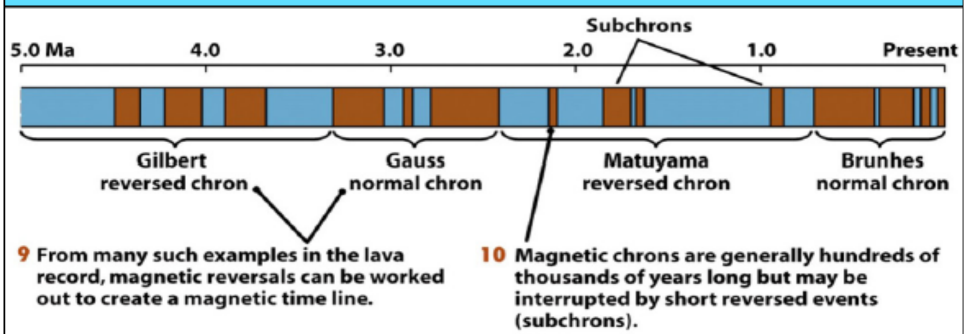

Figure 2-10 part 3
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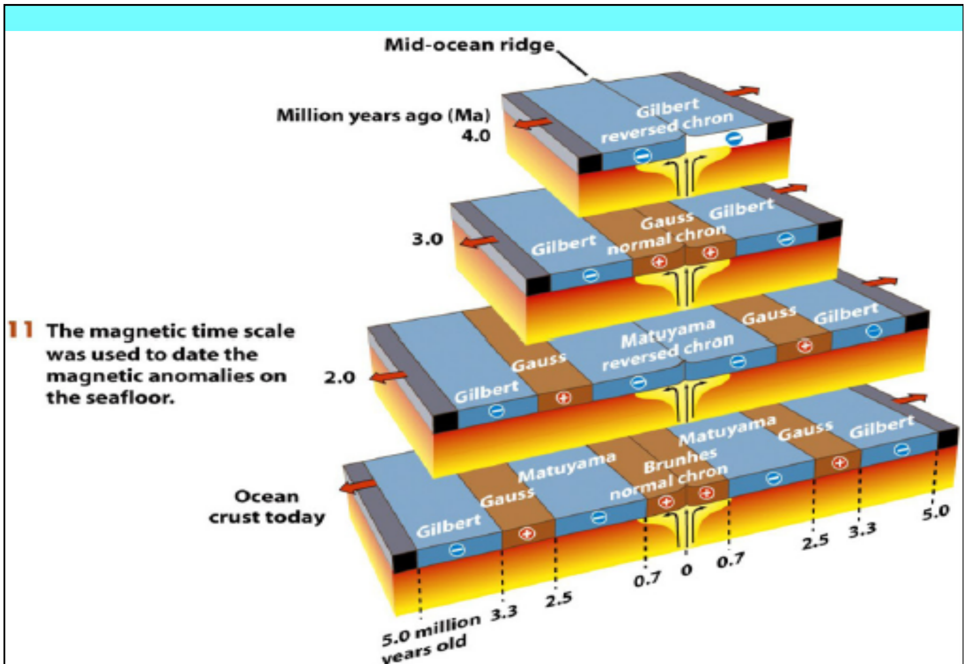

Figure 2-10 part 4
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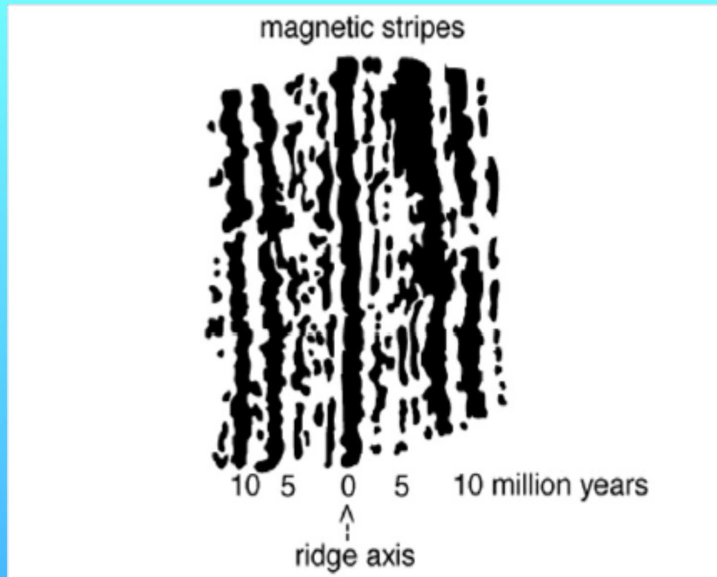

Pattern created by magnetic stripes along the Mid-Atlantic Ridge south of Iceland.

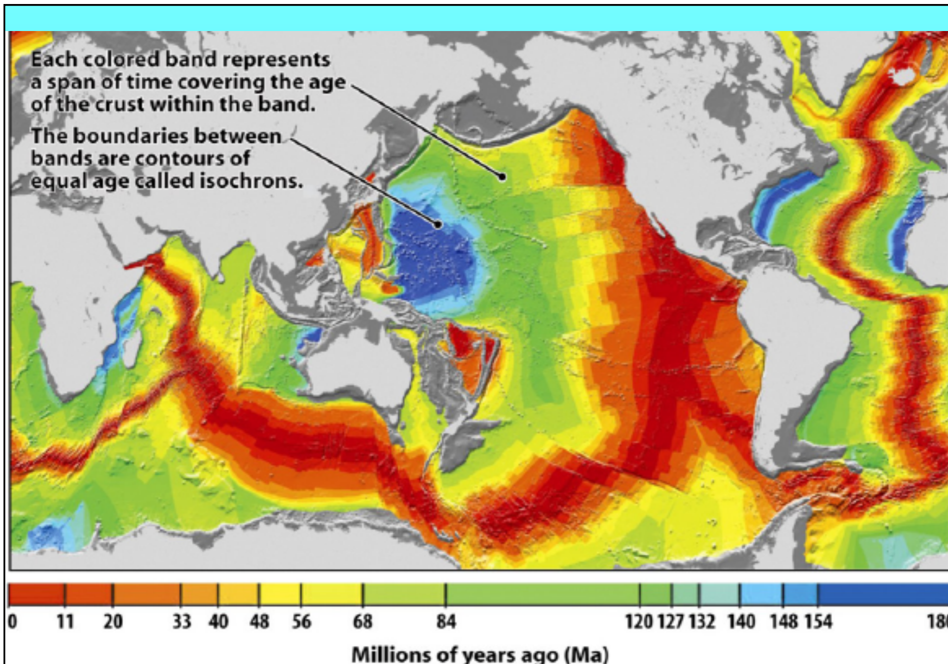

Figure 2-12
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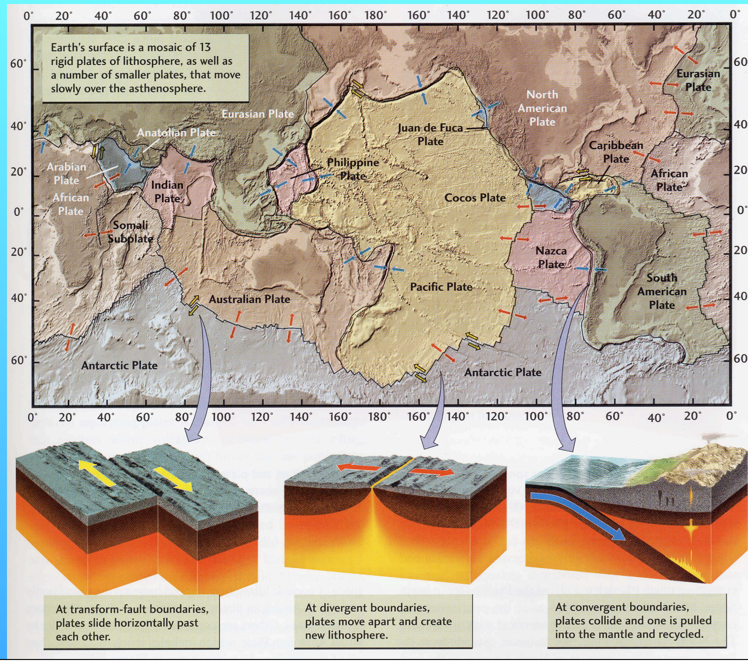
Plate mosaic and types of plate boundaries



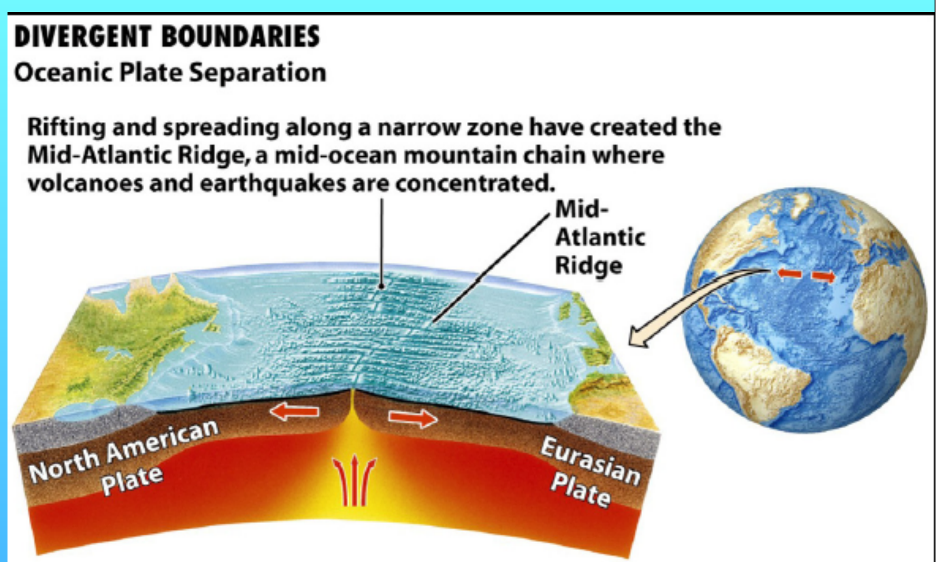


Figure 2-6a
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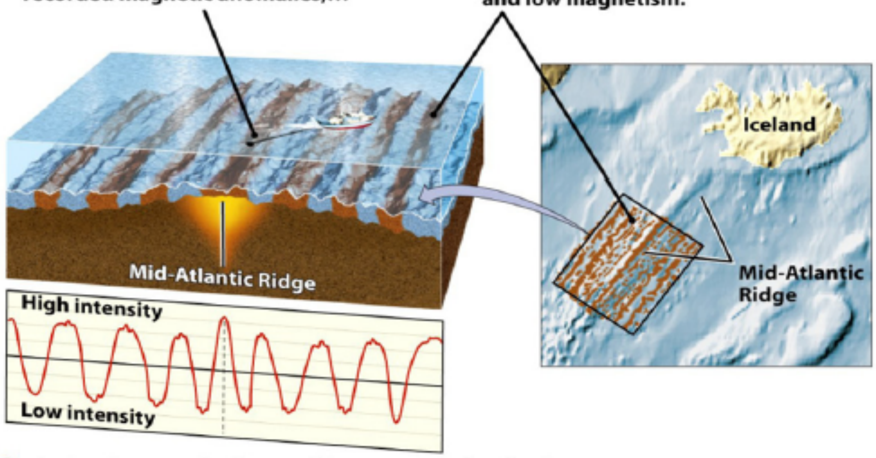
An oceanographic survey over the Reykjanes Ridge, part of the Mid-Atlantic Ridge southwest of Iceland, showed an oscillating pattern of magnetic field strength. This figure illustrates how scientists worked out the explanation of this pattern.

1 A ship towing a sensitive magnetometer recorded magnetic anomalies,...

2 ...alternating bands of high and low magnetism.



3 The bands proved to be roughly symmetrical on both sides of the Mid-Atlantic Ridge. But what was the meaning of these anomalies? Volcanoes would provide a clue.

Figure 2-10 part 1
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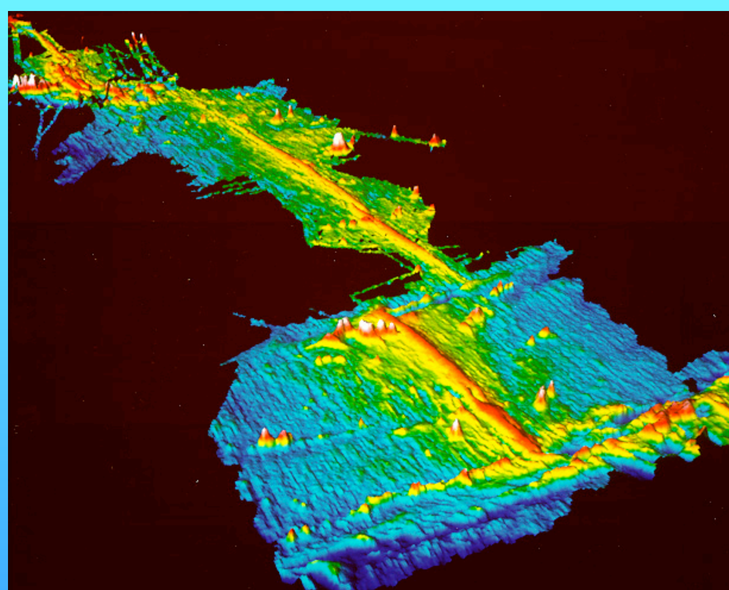
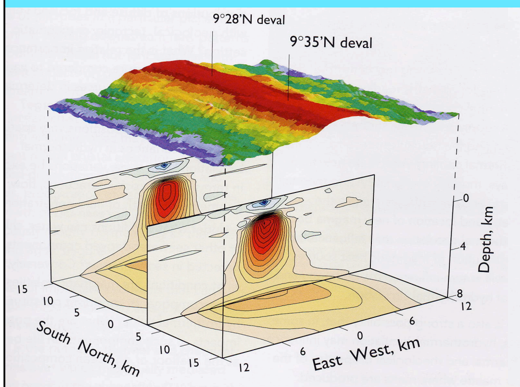
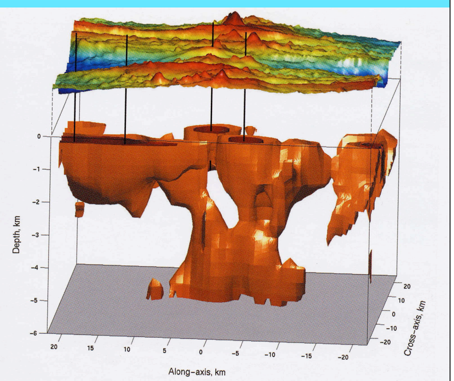
High-resolution ship survey of East Pacific Rise west of Mexico – roughly 100 mile-long seafloor image



Images of seismic wave velocities beneath mid-ocean ridges. Red areas depict areas of warmer mantle lying beneath the axis of seafloor spreading.





Seafloor spreading centers have yielded one surprise after another over the past 20 years. Perhaps the most surprising is the existence of unique communities of completely unknown organisms that survive in pitch dark by drawing energy from chemical reactions. At the right, you see the recently discovered Pompeii worm, the most heat-tolerant animal on Earth. The Pompeii worm *(Alvinella pompejana)* can survive an environment as hot as 80° C (176° F) — nearly hot enough to boil water. How the worm survives this heat remains a mystery, but is fascinating to biotech companies (as are the legions of bacteria that live on it).

DIVERGENT BOUNDARIES

Continental Plate Separation

In East Africa, an earlier stage of rifting and spreading has created parallel valleys in a zone with volcanoes and earthquakes.

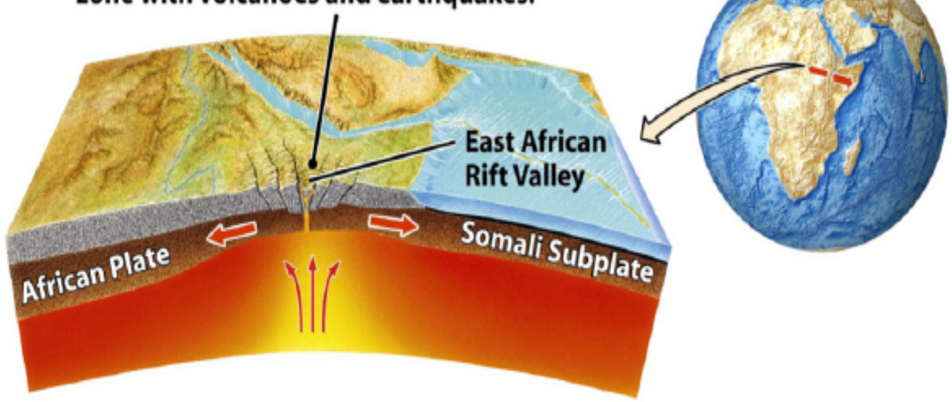


Figure 2-6b
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TRANSFORM-FAULT BOUNDARIES

Mid-Ocean Ridge Transform Fault

Spreading centers are offset by mid-ocean ridge transform faults, where the two oceanic plates slide horizontally past each other.

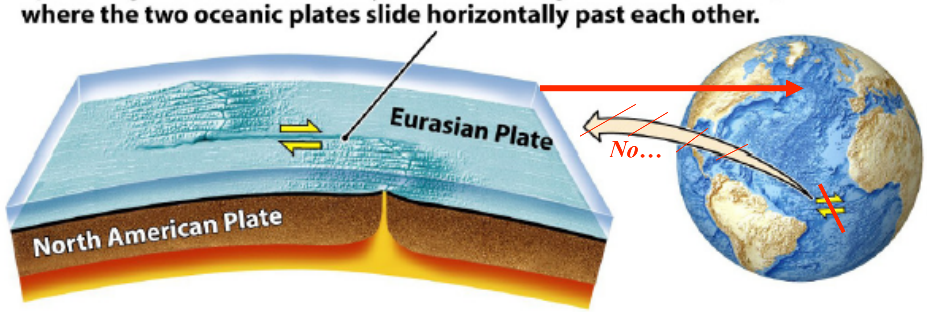

Figure 2-6f
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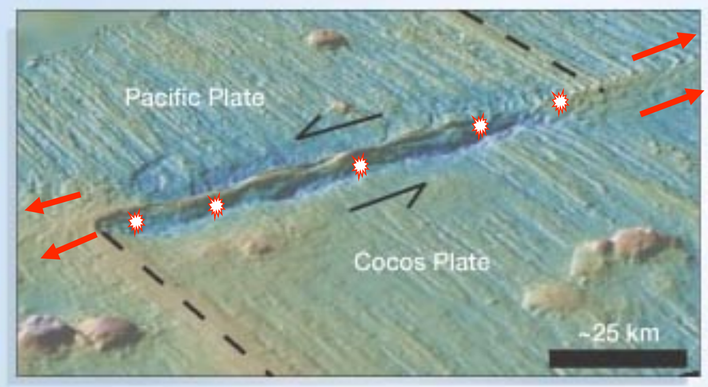
Fig. 19.19



Transcurrent or strike-slip plate boundaries also occur within continents. Not technically a “transform fault”, but we’ll forgive the textbook authors….

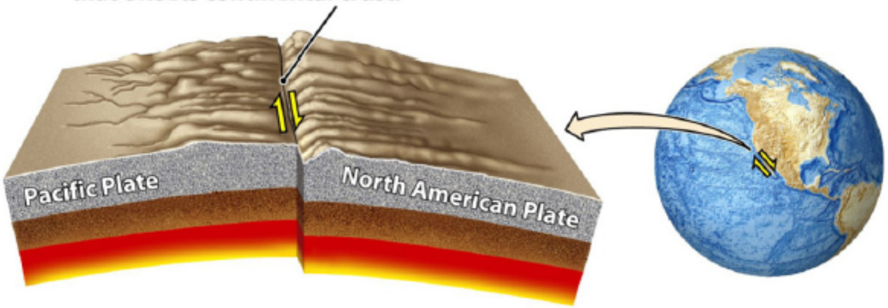


Figure 2-6g
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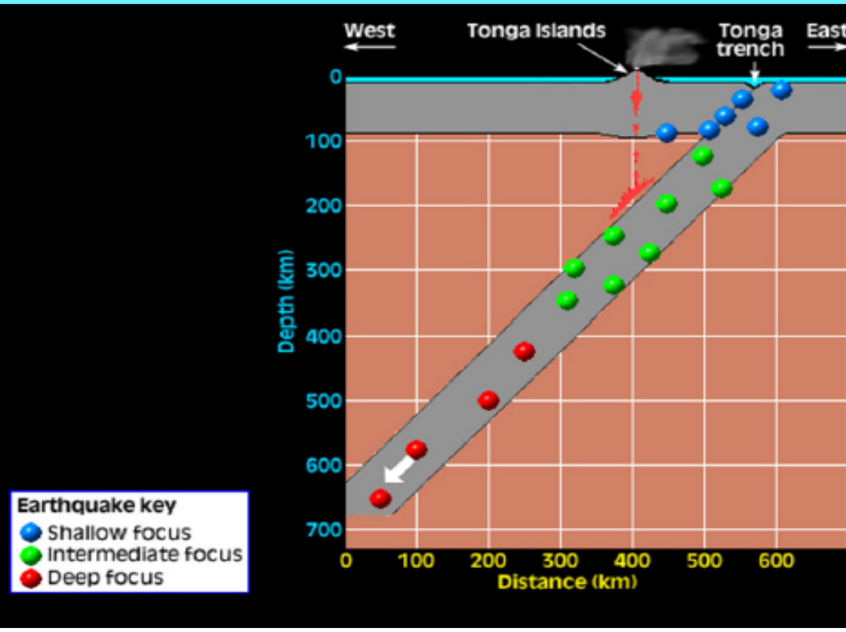
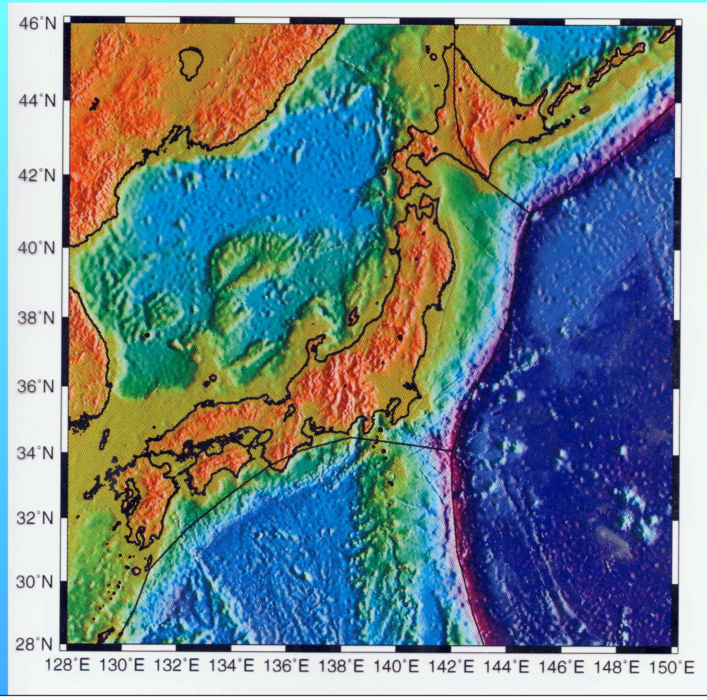
San Andreas fault, central plain of California

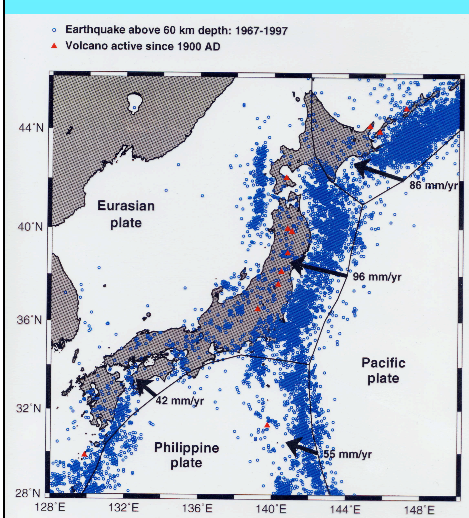
Convergent plate boundaries: Subduction zone

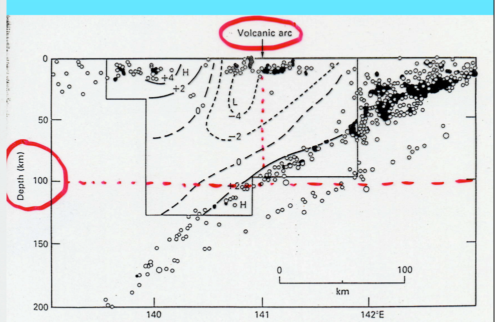


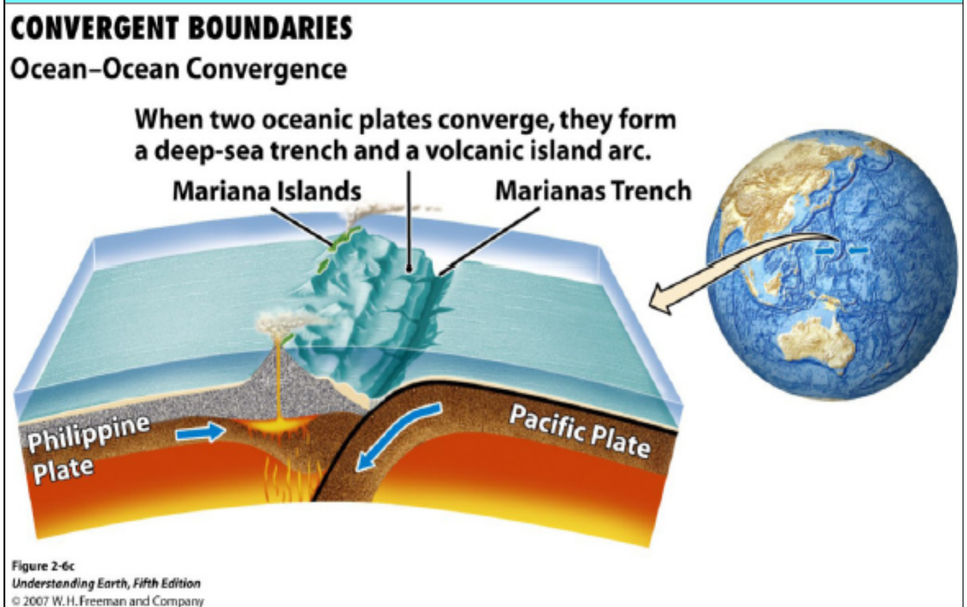
Subduction of the Pacific plate beneath Japan. An ocean-continent subduction zone. The deep-sea trench marks where the subducting plate bends as it enters the mantle.



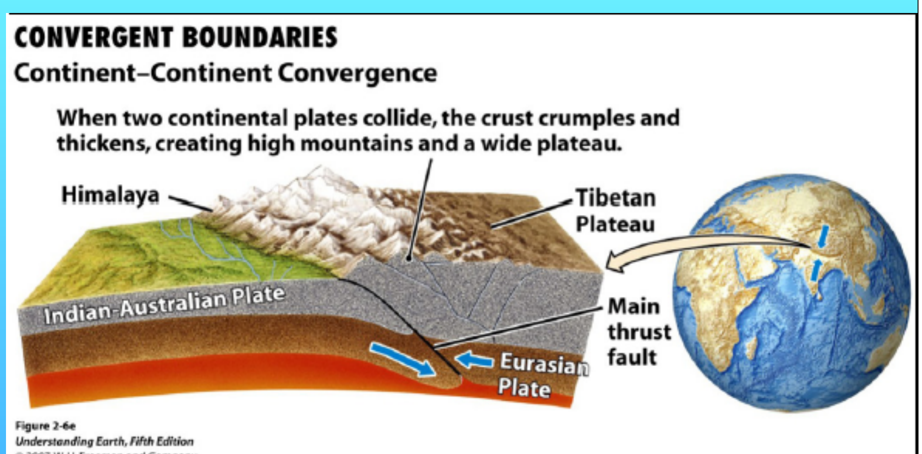
(LEFT) Earthquakes (blue dots) and volcanos (red)
(RIGHT) Depth cross-section of earthquakes (east-to-west) of Japan



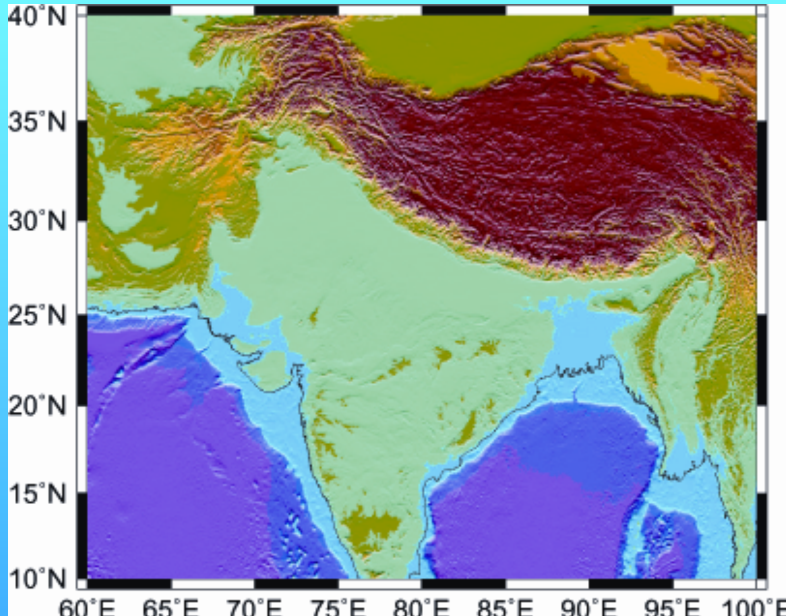




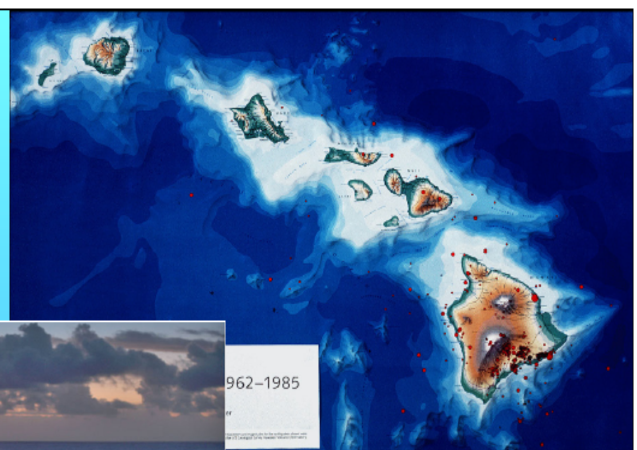
Convergent plate boundaries: Mountain uplift. Subduction not possible because both plates are too buoyant.

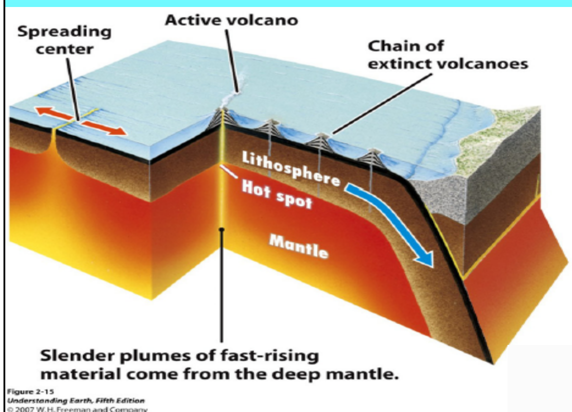


The Himalayan mountain belt: a continent-continent convergent boundary

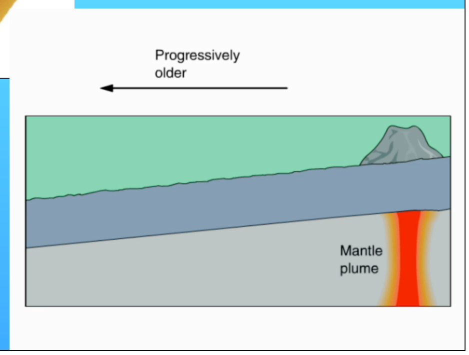


Hotspot island chains – another manifestation of plate tectonics

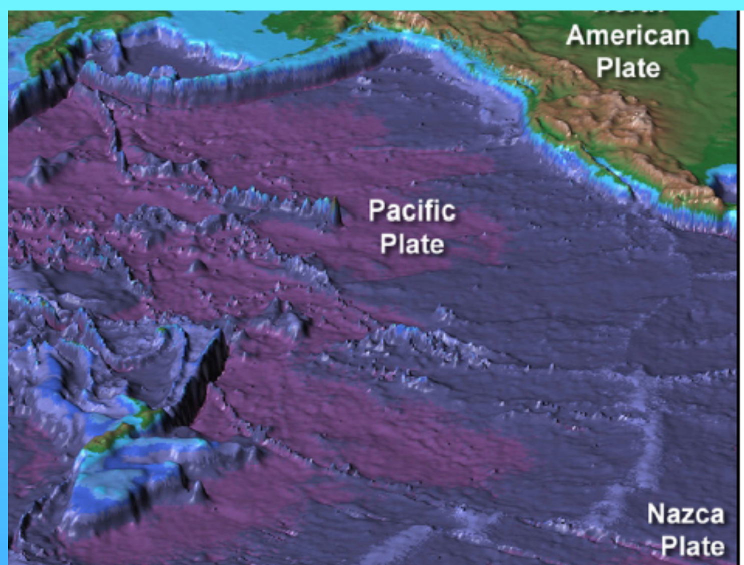




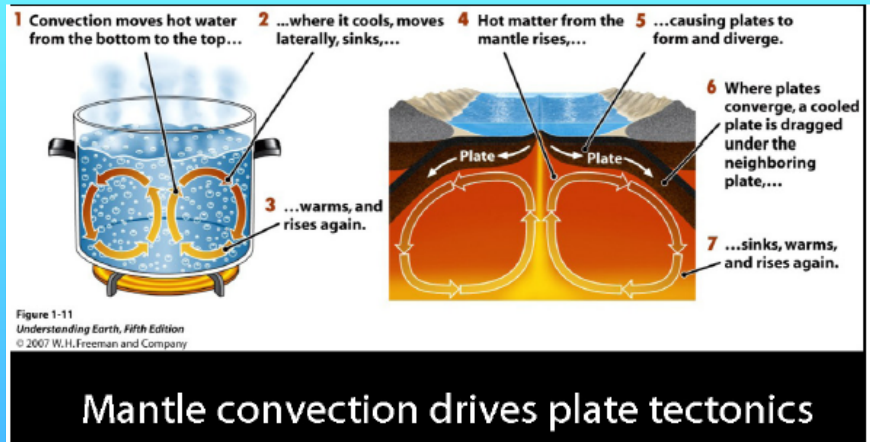
Animation: creation of hotspot volcanic chain



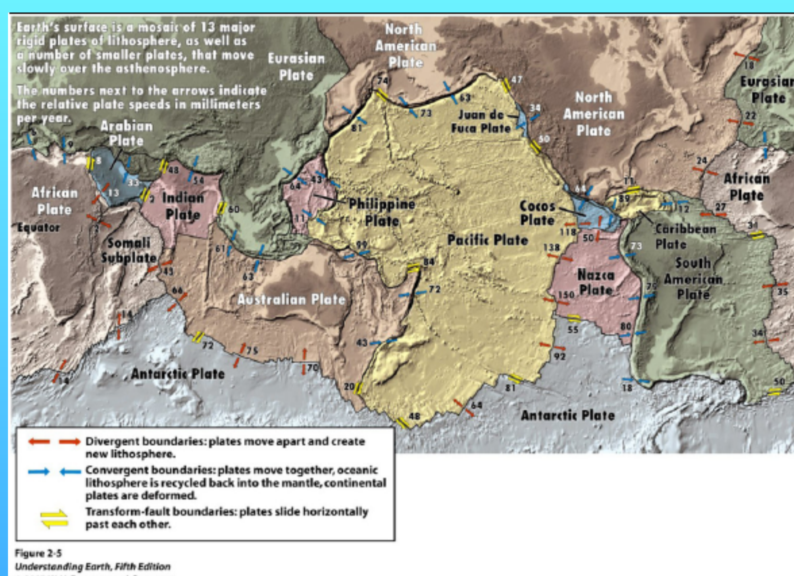
Pacific basin hotspot chains



Why do the plates move ? Convection



How fast Is plate motion ? Ranges from 1-200 millimeters per year (0.04 to 8 inches per year) – Known very precisely



Continents move WITH oceanic crust, not through it.